G21A-0427

2014 Fall AGU Meeting
San Francisco, CA.

JPL's Reanalysis of Historical GPS Data for the Second IGS Reanalysis Campaign

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Abstract

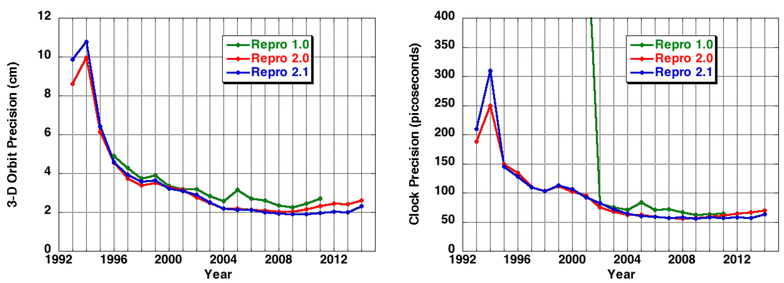
As an analysis center of the International GNSS Service (IGS), the Jet Propulsion Laboratory (JPL) has participated in the second IGS reanalysis campaign for its contribution to the 2013 International Terrestrial Reference Frame. While the IGS campaign requests products starting in 1994, our products span August 16, 1992 to present. Our contributions to the IGS include orbit and clock solutions for the Global Positioning System (GPS) constellation of satellites, GPS station positions, Earth orientation parameters, and estimates of zenith troposphere delay. Our satellite clock contributions are at 5-minute intervals for the entire period, but we also provide clock solutions at 30-second intervals for the period May 5, 2000 onward. For our entire reanalysis period, our products also include information on the phase biases and the widelane data combination from the network solutions. This information enhances precise point positioning for single receivers by enabling integer resolution of the GPS carrier phase biases without the need for nearby reference stations.

In this paper we present the processing strategy that we have used for this campaign, as well as results from the evaluation of precision and accuracy of our estimates of orbit positions, clocks, and Earth orientation parameters. This reanalysis of historical GPS data is the third that we have performed over the last 7 years. We show the evolution of the products from each campaign, highlighting the impact of successive changes to our processing approach. The most significant improvements in our most recent reanalysis occur for the periods from 2008 onward, with 3-D orbit and clock precision reaching 2 cm and 50 picoseconds, respectively. We also show the evolution of GPS-based reference frame realization from our successive reanalyses, where stabilities of < 0.5 mm/year have been achieved in each component of the translation parameters.

JPL Reprocessing Campaigns for GPS Orbit/Clock Products

Processing Version	Year Repro. Completed	Version Start/End	Description
1.0	2009	1996-01-07 to 2011-08-13	• Contribution to IGS "Repro-1" campaign using IGS05 reference frame.
2.0	2012	1992-08-16 to 2014-10-25	• First reprocessing using IGS08 reference frame. • Products facilitate single receiver integer phase ambiguity resolution.
2.1	2014	1992-08-16 to Present	• Second reprocessing using IGS08 reference frame. • Contribution to IGS "Repro-2" campaign. • Products facilitate single receiver integer phase ambiguity resolution.

Evolution of GPS Satellite Orbit and Clock Precision

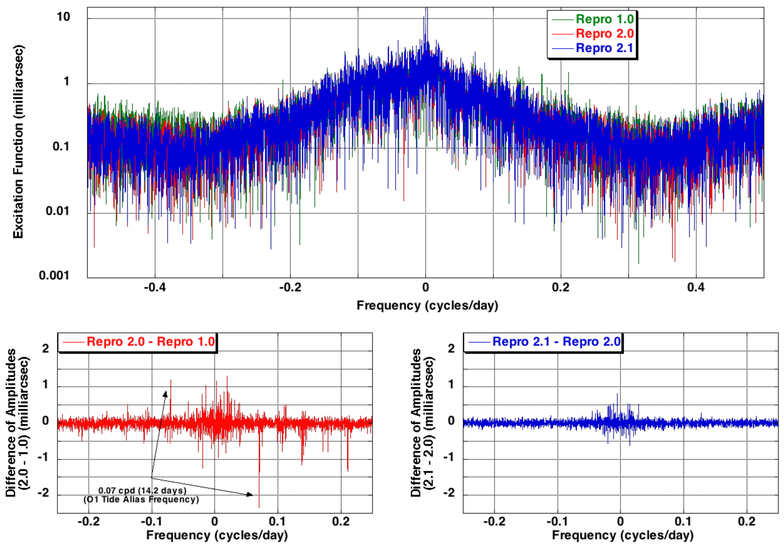


- Precision measured using annual median of daily RMS of differences during middle 5 hours of 6-hour overlapping period of adjacent-day solutions.
- Most noticeable improvements from Repro 2.1 versus 2.0 are after 2008.
  - Operational period and use of IGb08 (Repro 2.1) versus IGS08 (Repro 2.0).
  - Elevation-dependent data weighting.
  - Updated solar radiation pressure models.
- Degraded precision of Repro 2.1 versus 2.0 in 1992-1995.

Version 2.1 Processing Strategy

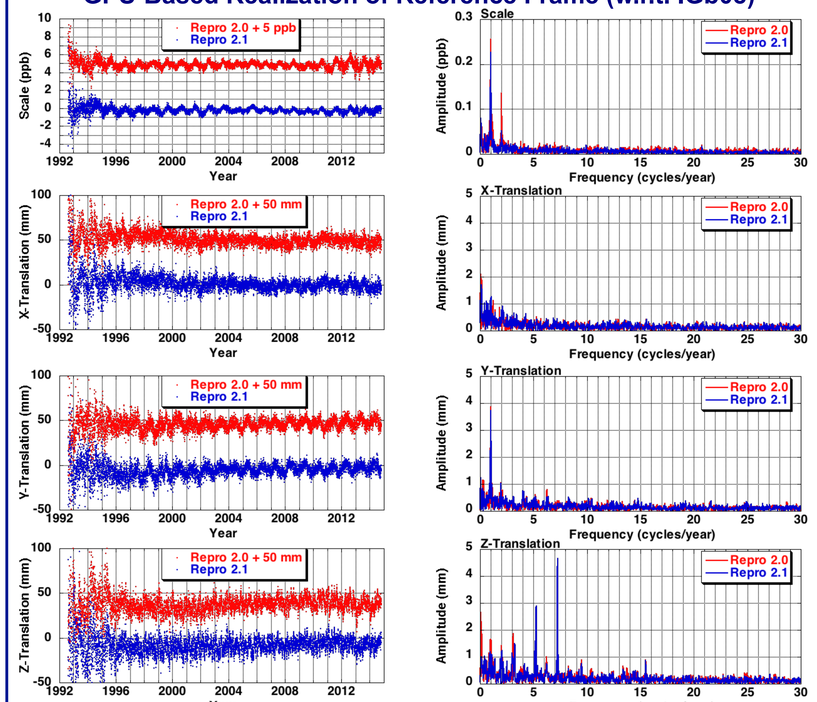
Software	GIPSY/OASIS 6.3
Orbit Arc	30 hours
Number of Stations	80 (40-80 before 1995-04-17)
Elevation Angle Cutoff	7 degrees
Station Information	IGb08 SINEX and Discontinuity
Receiver/Transmitter Antenna Calibrations	igs08.atx
Troposphere Mapping Function	GPT2 (Lagler et al., 2013)
A Priori Dry and Wet Troposphere Model	GPT2 (Lagler et al., 2013)
Solid Earth Tide (Geometric and Gravity)	IERS2010
Pole Tide (Geometric and Gravity)	IERS2010 (IERS2010 Mean Pole, including ocean load pole tide)
Ocean Tide Loading Model	GOT4.8ac with harddisp.f
Earth Orientation	IERS 2010 Tidal Model, EOPC04 (ITRF08)
Nutation	IAU2000A/IAU2006 (IAU2006A)
Static Gravity Field	EGM2008 (12x12, C20, C30, C40, C21, S21 per IERS 2010)
Ocean Tide Gravity Field	GOT4.8ac (convolution formalism)
Solar Radiation Pressure	GSPM13 (Sibois et al., 2014)
Albedo Model	Knocke (1989)
Antenna Thrust	IGS Recommendation
Transmitter Clocks	5-minute and 30-second Products
Second Order Ionosphere Correction	Modeled with ionosphere model IONEX (>= 1999), IRI2012 (<= 1998)
Yaw Rates	Estimated
Data Weighting	$\sin(\text{elevation})/\sigma^2$

Polar Motion Excitation



- Polar motion excitation derived from daily estimated values of polar motion bias and rate.
  - Power spectra uses estimates from 2000-12-30 to 2011-08-07.
    - Time series from all three reprocessing campaigns available.
  - Repro 2.0/2.1 have lower power than 1.0 at frequencies < -0.25 and > 0.25 cycles/day.
  - Repro 2.0 changes power at O1 tidal alias frequency, and overtones.
    - Increase in retrograde, but decrease in prograde.
    - May be associated with adoption of IAU2006A nutation model (includes tidal effects)
  - Repro 2.1 and Repro 2.0 have very similar spectral distribution.

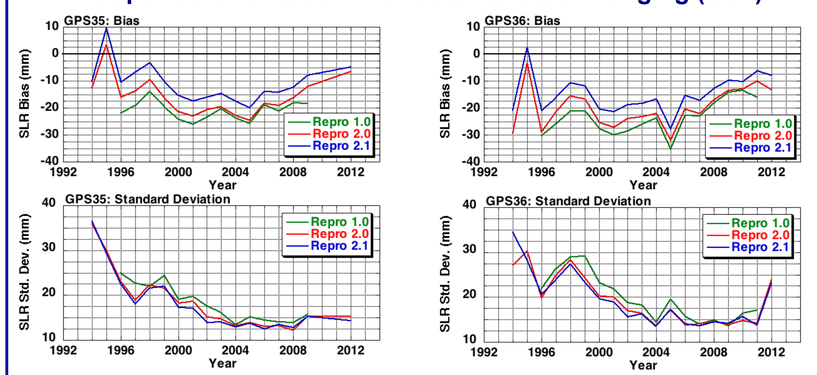
GPS-Based Realization of Reference Frame (w.r.t. IGb08)



	Bias (Epoch=2000.0, mm and ppb)				Drift (mm/yr and ppb/yr)			
	TX	TY	TZ	Scale	TX	TY	TZ	Scale
Repro 1.0	0.9	-3.5	-10.1	1.3	-0.4	-0.1	0.2	-0.03
Repro 2.0	2.1	-5.5	-14.8	-0.2	-0.4	0.2	0.3	0.0
Repro 2.1	2.3	-8.3	-10.8	-0.3	-0.3	0.4	0.3	0.0

- Repro 2.1 has lowest scatter in reference frame parameters.
  - Particularly in scale after 2010 and before 1994.
  - From improved approach for recovery of reference frame parameters, and use of elevation dependent data weighting.
- Repro 2.1 eliminates dependence of Z-translation on solar cycle.
  - From use of second order ionosphere correction (e.g., Garcia-Fernandez et al., 2013).
- Repro 2.1 Z-translation has higher energy at 5th and 7th draconitic frequencies.
  - Possibly from new solar radiation pressure model.

Independent Validation with Satellite Laser Ranging (SLR)



- SLR bias reduced with each reprocessing, most significantly with Repro 2.1.
  - Application of antenna thrust in Repro 2.1.
- Improved accuracy (lower standard deviation) with each reprocessing.